

# Using Drainage Information Obtained from Aerial Photographs

MERLE PARVIS

Research Engineer

Joint Highway Research Project

Purdue University

## SYNOPSIS

This paper presents uses of drainage information obtained from aerial photographs. Introductory items of the paper are those concerning the status of aerial photography in the state, and the study of aerial photographs for drainage information. The Joint Highway Research Project's drainage mapping program is given as an application of airphoto drainage information to engineering practices.

The main section of the paper treats several examples of hydrologic problems which can be examined and studied by means of airphotos. For example, the delimiting and measuring of drainage basins is accomplished readily from airphotos.

The final sections briefly review the importance of drainage patterns in engineering soils mapping; a status map of this program is included. Also listed are various agencies which have requested drainage maps or relative information.

This paper supplements a report entitled, "Status of Drainage Mapping from Airphotos in Indiana," which was presented at the 35th Annual Purdue Road School in April, 1949, at Purdue University, Lafayette, Indiana; and a report entitled, "Drainage Pattern Significance in Airphoto Identification of Soils and Bedrocks," which was presented at the 29th Annual Meeting of the Highway Research Board in December, 1949, at Washington, D. C.

## INTRODUCTION

Land, water, and air make up the primary elements of the earth. The inter-relationship of these elements constitute its physical features. The land is recognized by its relief, a physical feature dealing with differences in elevation, and by its drainage, dealing with water. Drainage is considered to be all natural channels and basins (i.e., streams, lakes,

and swamps) which contain water, or through which water flows on its journey to the ocean or into a closed basin. Included with these natural forms are such artificial forms (i.e., canals, ditches, and reservoirs) as man has seen fit to construct.

Drainage systems, being mostly surface features, are recorded on aerial photographs. Airphotos, then, become one of the most important tools of the civil and sanitary engineer.

When an engineer flies over a drainage feature, he looks down on it, perhaps he gets the pilot to circle the spot, and then he lands. The flight is completed in a matter of minutes. What he has seen he has to remember. Then, too, he has been so far above the feature that he has missed the details. On the other hand, the camera records what the eye misses and the images of the details are on the prints. Because the ground is not moving under the interpreter's stereoscope, he can study the feature for all the time required to investigate the details of the feature.

Existing aerial photographs usually meet the needs of the surveyor and engineer. However, special "unscheduled" photographs prove their worth in highway planning, and in county drainage programs, also.

### AERIAL PHOTOGRAPHS OF INDIANA

Indiana's engineers are fortunate in that the state has been photographed completely from the air. Aerial photographs of Indiana have been produced by many agencies, some of which are as follows:

1. The Tennessee Valley Authority has 1936 photographs, scale 1:15,000, covering Posey and Vanderburg counties.
2. The Purdue Agriculture Experiment Station has on file photographs of several counties (taken as early as 1929) for Soil Survey mapping.
3. The Chicago Aerial Industries, Inc., in 1946 made Sonne strip photographs of several sections of state and U. S. highways. The company also photographed the area bordering Lake Michigan in 1950.
4. The Soil Conservation, before 1936, had obtained airphotos for a dozen counties in east-central Indiana.
5. The Edgar Tobin Aerial Surveys, San Antonio, Texas, holds aerial photographs of parts of Posey, Vanderburg, and Warrick counties, south of the 38th parallel.

6. The U. S. Geological Survey has aerial photographs for many quadrangles in Indiana. The scales of these pictures vary from 1:14,000 to 1:46,200.
7. Jack Amman Photogrammetric Engineers, San Antonio, Texas, photographed that portion of the state north of the 39th parallel in 1952 for the Army Map Service. The scale of these pictures is 1:63,000.
8. During the winter of 1951-52 the Evansville area was photographed for the Indiana State Highway Department by Clark Aerial Survey Corp., Plymouth, Michigan. The scale of these airphotos is 1:9,600.
9. Abrams Aerial Survey Corp., Lansing, Michigan photographed a strip three quadrangles wide along the northern boundary of Indiana in 1952 for the U. S. Geological Survey. These pictures have a 1:24,000 scale.
10. Prior to 1943, the U. S. Department of Agriculture had obtained aerial photographs for the entire state (Scale: 1:20,000). By the end of 1954 a complete set of new photographs had been obtained. Index sheets may be purchased at a nominal cost for these photographs. (See Table I.) In addition, 22 counties are under contract to be rephotographed.

One U. S. D. A. index sheet is required for all counties except the following:

TABLE I

County	No. of Index Sheets
Clay .....	2
Fountain .....	2
Gibson .....	4
Greene .....	4
Harrison .....	3
Jasper .....	2
Knox .....	4
Lake .....	2
Laporte .....	4
Madison .....	2
Porter .....	2
Vermillion .....	3
Warrick .....	4

## STUDY OF AIRPHOTOS FOR DRAINAGE INFORMATION

Let a person inexperienced in airphoto interpretation view an aerial photograph. What does he see? He sees a conglomeration of gray tones at first. After a while these gray tones "assemble themselves" into a kind of orderly arrangement for the observer. He soon is conscious of areas and lines. These areas and lines become terrain features when he views the prints stereoscopically.

### *Identification of Terrain Features*

Terrain has been defined as "a part of the land surface of the earth, limited in extent" (4, p. 7)\*. Webster has defined terrain as "a tract or region of ground immediately under observation." These two



Fig. 1. An area in central Putnam County. Recorded on this single airphoto are the following natural and cultural features:

RR—Railroad	W — Woods
TC—Telephone Cable	H — Highway
PL—Pipe Line	T — Town
O — Orchard	Q — Quarry
F — Field	M — Cement Mill
SH—Sinkholes	S — Stream

\* Numbers in parentheses refer to bibliography.

definitions indicate that terrain is any area on the earth which can be viewed and studied by an observer. By employing aerial photographs, the observer is no longer restricted to the view of an area which he gets as he stands on a vantage point within that area. He can study a river and all its tributaries as easily as he can study the stream bank upon which he might be sitting while fishing.

Figure 1 is a vertical airphoto presenting terrain features which are first impressions to the observer. The railroad has long tangents and long, smooth curves. The telephone cable is like a spider web; individual supporting poles can be seen. The buried pipe line is detected by the ragged, nearly white line; this "whiteness" is the result of the drying out of the disturbed and loosened soil. The regular rows of dark gray dots like so many map pins are trees in an orchard. Rectangular lighter gray areas are fields separated by fences or lines between cultivation. Sinkholes are near white circles with dark dots in their centers. The very dark areas—some rectangular, some irregular—of botryoidal textural appearance are wooded tracts. Highways have shorter tangents and more and sharper curves than railroads; principal highways are built "cross-country" while many county roads follow section lines. Towns are groups of buildings in a checkerboard network of streets. A quarry is a vertical-sided depression of irregular shape. Mill build-

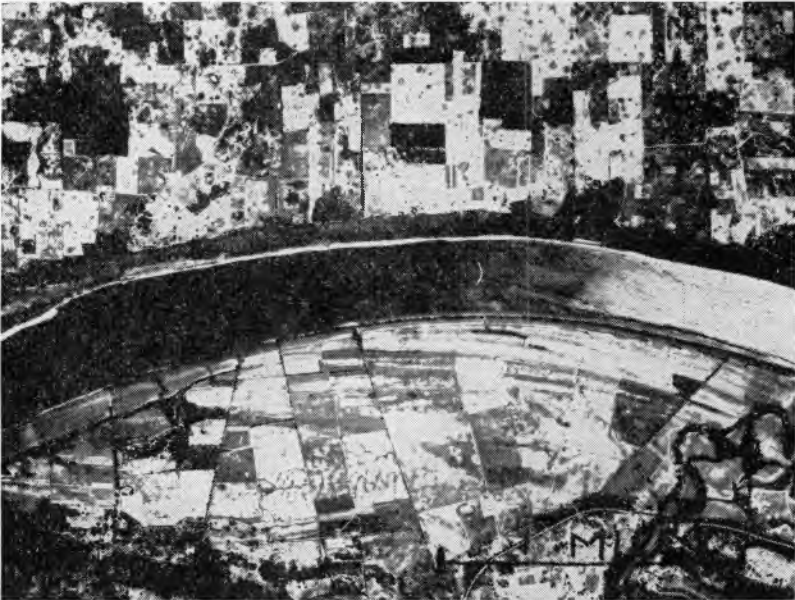


Fig. 2. Section of Ohio River between Kentucky (lower half) and Harrison County, Indiana (upper half). The direction of flow is to the left.

ings are long narrow rectangles—grouped. A stream is a meandering ribbon of varying width; in this case its banks are tree-lined

### *Tonality*

Caution must be exercised in the analysis of stream characteristics from airphotos because conditions at the time of photography produce variations in the lightness and darkness of the prints. In Figure 2 the "white" part of the river on the right is caused by sunlight reflecting from the water directly into the camera lens since the picture was taken in mid-morning as indicated by the shadows of the trees. The white spot has obliterated some of the shore features. The center portion of the stream's image has a "scaly" appearance; this means that the surface was roughened by the wind. The left hand portion is dark gray in tone; this normally indicates that the water is clear and deep, which is the condition of the Ohio River in the picture.

## STEREOSCOPIC EXAMINATION OF HYDROLOGIC FEATURES RECORDED ON AERIAL PHOTOGRAPHS

The study of the hydrologic features of the earth by means of airphotos, both in the office and in the field, is best done with the aid of a stereoscope, with the photo-interpreter viewing pairs of consecutive prints. Otherwise, he is likely to miss many of the details on the prints which are so important in their contribution to the identification of the conditions being investigated (1, p. 773).

If a refraction type stereoscope is used, it must be adjusted to "fit" the observer's eyes; i. e., the distance between the centers of the lenses of the instrument should be nearly the same as his interpupillary distance. If the observer does not know his eye base, this adjustment can be made easily by viewing a distant object through the stereoscope as in Figure 3. By using both hands, the lenses are moved apart or together until a "good" (although blurred) single image of the object is obtained. This should be the proper setting of the instrument for the particular observer. When the lenses are set too far part, the terrain on the airphotos appears "dished" (bowl-shaped), and when they are set too close together the terrain appears "humped" (dome-shaped).

It is desirable always that the prints be placed in such a manner that the interpreter is facing the light source and that the light is uniform. This is to help eliminate shadows of desk objects and to alleviate the interpreter's tensions which might be caused by their effect.

For proper stereoscopic fusion, the flight lines should be established on the airphotos and the pair of overlapping prints oriented so that the



Fig. 3. Adjustment of stereoscope.



Fig. 4. Interpreter marking drainageways on airphotos with the aid of a pocket stereoscope. Besides a stereoscope, wax pencils, erasers, a sandpaper pad, a bottle of carbon tetrachloride and some facial tissues are accessory items of equipment.



Fig. 5. Uncontrolled Mosaic of a portion of Knox County (3). The meandering rivers can be traced for miles. The relationship of the flood plain features to the rivers is strikingly evident.



Fig. 6. Till Plain Topography. (Purdue Photo)



flight lines are coincident. However, the orientation of a pair of air-photo prints under the stereoscope by the so-called trial and error method usually suffices for scanning the prints and marking the drainageways, if the observer sees the fused image comfortably. (See Figure 4.)

The lenses of the stereoscope should be kept directly over the object being observed on the prints for "true" stereoscopic fusion. Otherwise, the surface of the ground might appear "to slope the other way" and the streams "to run uphill."

Occasionally it is necessary to assemble an uncontrolled mosaic for a portion of a county in order to check the continuity of the marked drainage lines. The mosaic is assembled similarly to the one in Figure 5 except that the alternate prints only are stapled to the board and the others used for the stereoscopic study.

### APPLICATION OF AIRPHOTO DRAINAGE INFORMATION TO ENGINEERING PRACTICES

A paradoxical conclusion might be drawn after observing Figure 6 that Indiana's terrain is all gently rolling and that state-wide drainage problems are non-existent. If that were true, there would be little need for the hydrological phase of engineering. However, drainage problems do exist and the engineer, by equipping himself with the stereoscope, airphotos, and an understanding of how to use them, can simplify those problems.

#### *Status of Drainage Mapping in Indiana*

The dissemination of information concerning the surface of the earth is perhaps best brought about by the use of maps. It is expedient, then, that information on aerial photographs, in order to be of greatest value to engineers, be presented in the form of maps.

A drainage map of a county in Indiana, as developed from air-photos, is a planimetric representation on paper (or linen) portraying the terrain features representing water courses, such as flowing streams, field gullies, lakes, etc. The maps are plotted on some form of projection (e. g., polyconic) and to a selected scale (e. g., 1" = 1 mi.). These hydrologic features are shown on the drawings by conventional signs and symbols; and their locations on the map are in the same relation to each other as the features themselves exist in their true positions on the ground (6). (See Figure 7.) Drainage maps have been compiled from airphotos for 84 Indiana counties.

Drainage mapping from airphotos of the several counties in Indiana has been in progress since 1946 in the Airphoto Laboratory of



Fig. 7. Drainage Map of Wayne County, Indiana. This map was compiled to a scale of 1" = 1 mile on a polyconic projection base map traced from the 1937 highway and transportation map, Wayne County. Slight discrepancies in the base map grid were "adjusted" to agree with the airphotos. The trend of the major streams is to the southwest.

the Joint Highway Research Project at Purdue University (8). Only eight counties remain to be mapped. Table II lists the completed maps by county, the date each map was completed, and the person in charge of its compilation.

The compilation of these maps has been discussed previously in a paper entitled, "Advancements in the Development of Drainage Maps from Aerial Photographs." It was presented at the 34th Annual Purdue Road School in February, 1948, at Purdue University (5).

The cost of constructing these maps is approximately 1½ man hours per square mile. This cost is for the entire operation, from the initial marking of the drainageways on the airphotos to the final drafting of the maps themselves.

TABLE II  
LIST OF COMPLETED DRAINAGE MAPS  
of  
INDIANA COUNTIES  
(Prepared from Airphotos)

<u>County</u>	<u>Date Completed</u>	<u>Director</u>
Adams	Jan., 1954	P. T. Yeh
Allen	Dec., 1950	M. Parvis
Bartholomew	Oct., 1947	M. Parvis
Benton	Feb., 1955	P. T. Yeh
Blackford	Apr., 1948	M. Parvis
Boone	Apr., 1954	P. T. Yeh
Brown	Nov., 1946	M. Parvis
Carroll	Sept., 1954	P. T. Yeh
Cass	Feb., 1948	M. Parvis
Clark	Nov., 1947	J. C. Stevens
Clay	Apr., 1947	M. Parvis
Clinton	May, 1954	P. T. Yeh
Crawford	Dec., 1952	P. Montano
Daviess	Sept., 1953	M. Parvis
Dearborn	Oct., 1947	M. Parvis
Decatur	Nov., 1948	M. Parvis
De Kalb	Apr., 1953	P. T. Yeh
Delaware	Jan., 1954	P. T. Yeh
Dubois	Feb., 1953	L. R. Magnusson
Elkhart	Mar., 1950	M. Parvis
Fayette	Jan., 1947	M. Parvis
Floyd	Mar., 1947	M. Parvis
Fountain	July, 1946	S. T. Yang
Franklin	Feb., 1947	M. Parvis
Gibson	Dec., 1953	M. Parvis
Grant	Apr., 1948	M. Parvis
Greene	May, 1953	L. R. Magnusson
Hamilton	Mar., 1954	P. T. Yeh
Hancock	May, 1948	C. R. McCullough
Harrison	May, 1953	M. Parvis
Hendricks	Mar., 1949	C. R. McCullough
Henry	May, 1947	W. S. Pollard, Jr.
Howard	May, 1950	M. Parvis
Jackson	Nov., 1947	F. K. Dawson
Jasper	Aug., 1950	M. Parvis
Jay	Dec., 1953	P. T. Yeh
Jefferson	May, 1948	M. Parvis
Jennings	Nov., 1949	M. Parvis
Johnson	Sept., 1949	M. Parvis
Knox	Feb., 1952	M. Parvis

TABLE II—(Continued)

County	Date Completed	Director
Lagrange	Oct., 1952	M. Parvis
Lake	Dec., 1949	M. Parvis and R. D. Miles
Laporte	Apr., 1949	A. M. Johnson
Lawrence	Feb., 1953	L. R. Magnusson
Madison	Mar., 1954	P. T. Yeh
Marion	Aug., 1947	M. Parvis
Martin	July, 1948	M. Parvis
Miami	Mar., 1953	L. R. Magnusson
Monroe	Oct., 1947	C. J. Van Til
Montgomery	July, 1946	J. D. Mollard
Morgan	June, 1949	M. Parvis
Newton	Oct., 1954	P. T. Yeh
Noble	Mar., 1953	L. R. Magnusson
Ohio	Jan., 1947	M. Parvis
Orange	Mar., 1953	L. R. Magnusson
Owen	July, 1949	M. Parvis
Parke	June, 1946	M. Parvis
Perry	Nov., 1951	M. Parvis
Pike	Feb., 1953	L. R. Magnusson
Porter	Oct., 1948	M. M. Davis
Posey	Feb., 1953	L. R. Magnusson
Putnam	Sept., 1946	M. Parvis
Randolph	Dec., 1952	P. Montano
Ripley	Apr., 1948	M. Parvis
Rush	May, 1947	C. R. McCullough
St. Joseph	June, 1947	M. Parvis
Scott	Feb., 1949	M. Parvis
Shelby	Feb., 1948	M. Parvis
Spencer	June, 1951	M. Parvis
Starke	Jan., 1948	M. Parvis
Steuben	Aug., 1953	M. Parvis
Sullivan	Oct., 1952	M. Parvis
Switzerland	Jan., 1947	M. Parvis
Tippecanoe	Jan., 1949	M. Parvis
Tipton	Sept., 1951	M. Parvis
Union	Jan., 1947	M. Parvis
Vanderburgh	Apr., 1951	M. Parvis
Vermillion	Oct., 1946	M. Parvis
Vigo	Nov., 1946	M. Parvis
Warrick	Jan., 1950	M. Parvis
Washington	Dec., 1952	P. Montano
Wayne	Aug., 1949	M. Parvis
Wells	Apr., 1954	M. Parvis
White	Dec., 1954	P. T. Yeh

## AIRPHOTO INVESTIGATION OF SELECTED EXAMPLES OF HYDROLOGIC PROBLEMS

A problem is "anything that is required to be done." (Webster) The solving of problems often involves the marshalling of all kinds of information. Airphotos are veritable depositories of hydrologic information. While they are not a "cure-all" for every situation, they can prove to be invaluable aids to the engineer. Several examples of their usefulness are herein set forth.

### *Watershed Areas*

One of the most important uses of aerial photographs is the delimiting, measuring, and scrutinizing of drainage basins. In Figure 8 the watershed selected for an example is shown as a shaded spot on the map, and it is indicated by a dashed line on the airphoto. It will be noted that the culvert is in Tippecanoe County. By using aerial photographs, the area of the watershed can be obtained by the Tippecanoe County Road Supervisor without expense to Warren County. The area of the drainage basin, as measured, is approximately 600 acres. From this information the present drainage structure in the highway can be checked for adequate waterway opening.

If for any reason a replacement structure is contemplated, the characteristics of the drainage basin can be determined by a detailed study of the airphotos and a runoff constant selected for Talbot's Formula if that formula is to be used in the design of a structure for the stream crossing. Let 0.6 be chosen since the upper reaches of the stream system are in slightly rolling country and the gradient of the main stem steep. It follows, then that a structure having a waterway opening measuring 8 feet by 10 feet would be adequate.



Fig. 8. A watershed in Warren County, Indiana. The patulous design of the stream system forms a subdendritic pattern.

Widths and lengths of streams can be measured on airphotos. For example, in this illustration (Figure 8), according to the scale of the photograph, the width of the Wabash River at the mouth of the tributary is approximately 350 feet. The greatest length of the tributary is about 2 miles as determined by a map measurer.

When construction for a new highway or the improvement of an old one is proposed, a drainage strip map compiled from airphotos is of much value. Figure 9 is a map of this type. The watersheds of all streams crossing the road can be measured and the data used in the design of the required highway structures.

In all probability the highway and railroad shown in Figure 10 were not planned with the aid of airphotos but the illustration shows what could be done in future planning. The number of drainage structures can be kept at a minimum if the roads are constructed on the divides between watersheds.

### *Stream Systems*

Some times it is desirable to study a portion of a stream system for drainage improvement. Such a study can be conducted very effectively by means of airphotos. For example, in Figure 11, the Little Wea Creek has a rather narrow drainage basin in its upper reaches; the divides of the basin are crests of eskers. This narrowness affects the

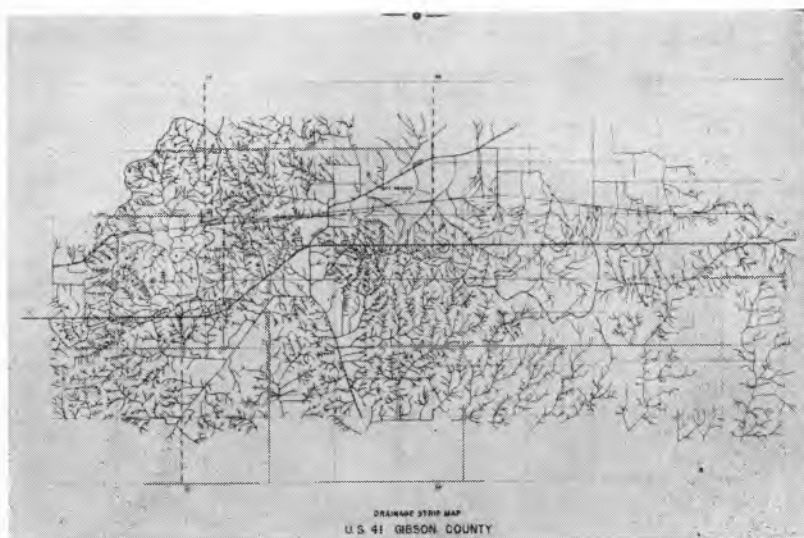


Fig. 9. Drainage strip map for a section of U. S. 41 in Gibson County, Indiana (2). The watersheds for all the bridges and culverts have been outlined with dashed lines.

time of concentration of runoff (i. e., increases the time). The creek heads and flows through a part of a morainic system (the Bloomington) of drift deposited by the Wisconsin glacier. Its "valley" is an esker trough, which is rather swampy. Apparently the morainic ridges have blocked the outlet of the "valley" to the southwest; this probably accounts for the stream's low gradient, resulting in extremely meandering courses, this also tends to delay runoff; frequent flooding occurs. However, much of the stream's channel has been straightened by dredging, thus shortening the channel and reducing channel storage; both speed runoff. An interesting fact is that the stream flows toward the northeast; this is contrary (directly opposite) to the trend of the streams in central Indiana. Another point of interest (not learned from airphotos) is that the 1952 "Drift Thickness" map does not disclose a buried valley along the course of the Little Wea even though the general dip of the bedrock is to the southwest.

Entire stream systems, likewise, can be studied by constructing a drainage map from airphotos. In Figure 12, Laughery Creek, in southeastern Indiana, is shown to drain portions of six counties. To make a map of this sort by conventional surveying methods would entail much time and expense. The time required in itself has been determined in some cases to be from 10 or 15 to 1 in favor of the airphoto

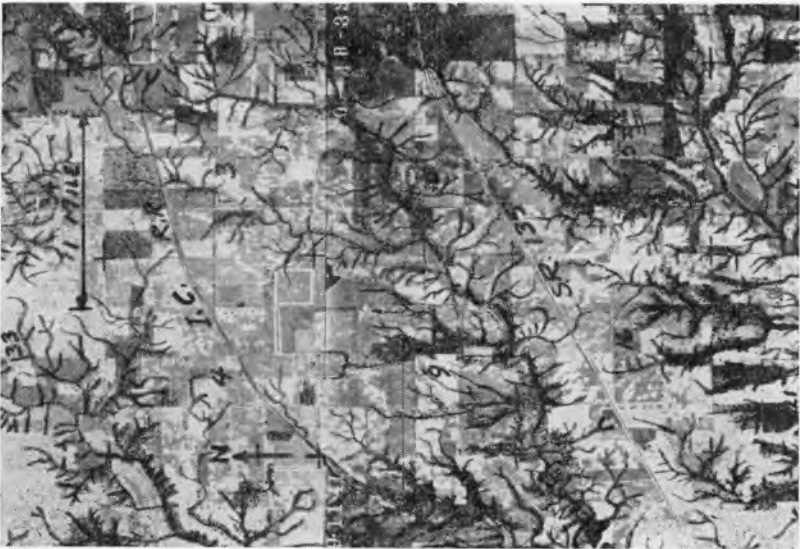


Fig. 10. Interfluves of an area in Johnson County, Indiana. The drainage-ways have been outlined on the airphotos with china marking crayon. State Highway 135 and the Illinois Central Railroad are constructed on the ridges. Both have very few culverts, and the necessary ones are small.

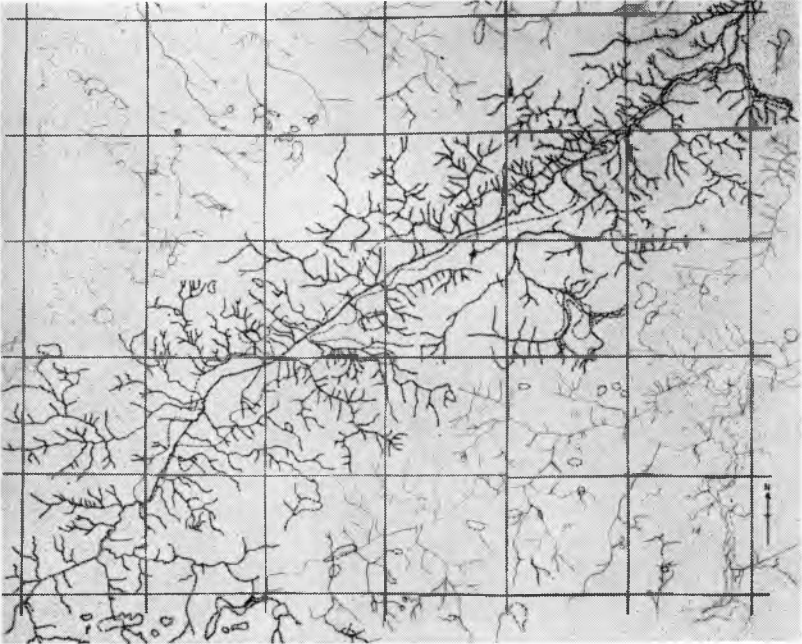


Fig. 11. Upper reaches of Little Wea Creek—southwest of South Raub, Tippecanoe County, Indiana. The dashed lines enclose the esker trough through which the stream flows and infiltration basins in the surrounding moraine.

method for the compilation of topographic maps. Since this is a planimetric map, the ratio probably would be much greater.

#### *Impeded Drainage*

After periods of hard rain, water often stands in the fields. Figure 13 illustrates such a condition. By having aerial photography of this sort it is not necessary for the engineer "to get out in the rain to see where the water goes." The ponds are areas of dark gray having smooth texture. The "dry" areas are light gray in tone; these are the knolls. The "wet" soils are registered on the airphotos in dark gray tones and are slightly rough in texture. These areas are depressed. Water accumulating in them is known as "depression storage;" runoff is thereby delayed. By bounding the depressed areas, ditch systems can be planned for draining the "pockets" (ponds).

#### *Erosion and its Control*

Sheet erosion is the initial form of erosion by water. It is identified on the airphotos by galled spots (blotches of light gray), or if vegetation is present, by areas of less vigorous crop growth. (See



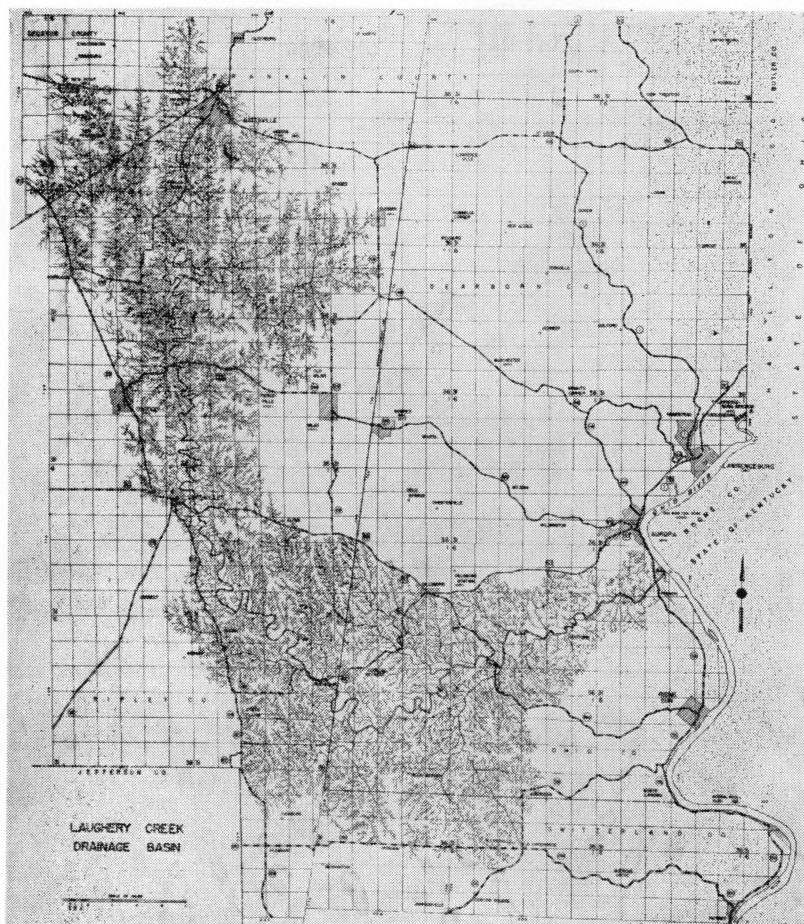


Fig. 12. Laughery Creek Drainage System—Southeastern Indiana. From Batesville to Olean the stream is flowing against the “Laughery” escarpment. Unable to cut across the hard ledges of Silurian limestone in this escarpment, it finds its way to the Ohio River through soft Ordovician shales. Laughery Creek flows in a valley 125 feet deep.

Figure 14.) The channelization of overland flow causes rills and gullies to develop. They are identified on the airphotos as hair lines, varying from white to black through the entire gray scale depending upon the type of soil and its moisture conditions. In the illustration, the gullies are “white-fringed;” this indicates a silty top soil and a dense clay subsoil. Sheet and gully erosion contribute to rapid runoff since there is no vegetation to retard it. The probability of damage by flash floods is increased.

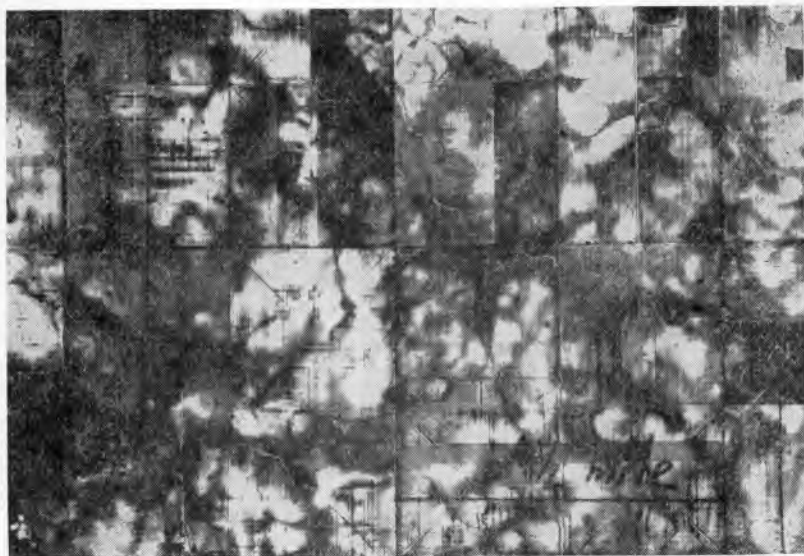


Fig. 13. Wet fields, central Indiana. The knolls are registered in light gray tones, the depressions in dark gray, and water standing in the fields in nearly black tones.

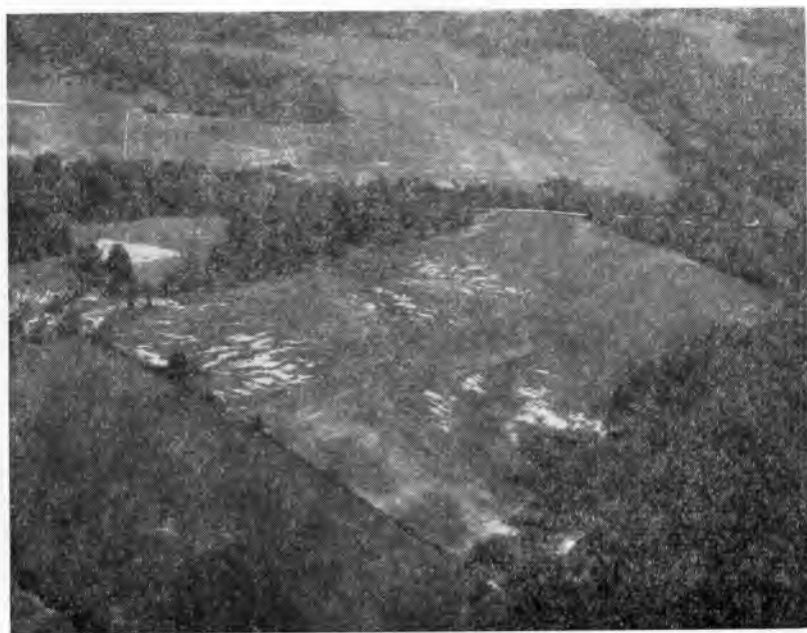


Fig. 14. Sheet and gully erosion—southeastern Indiana. (Purdue photo)

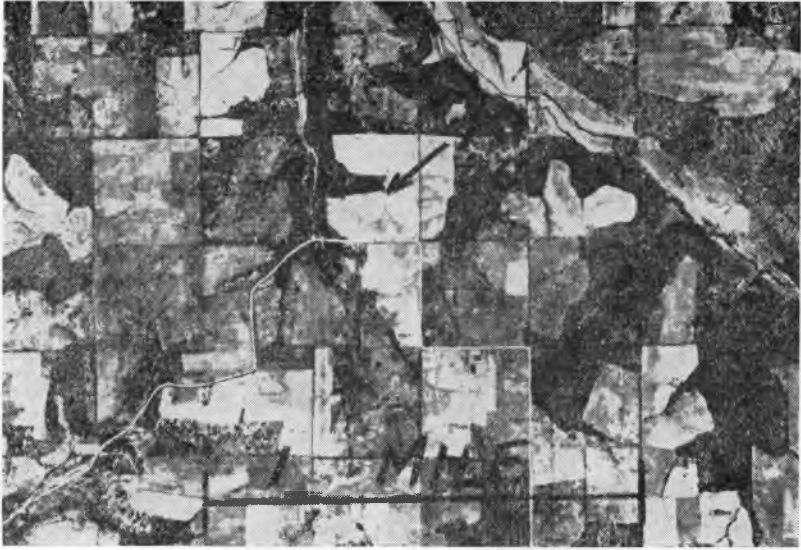


Fig. 15. Purdue Forage Farm prior to erosion control practices. (1951 Purdue photo)



Fig. 16. Purdue Forage Farm after erosion control measures were pursued. The dams for the farm ponds were constructed near the heads of the gullies in order to keep water storage capacities slightly more than the yield of each individual watershed. (1954 U.S.D.A. photo)



Fig. 17. Wabash River in flood—near Lafayette, Indiana. The main channel is the “white” band extending from upper right to lower left. (Chicago Aerial Industries, Inc., Photo from Purdue files.)

### *Erosion Control*

The use of “before-and-after” photographs is an excellent way in which to present measures taken for erosion control. The airphoto in Figure 15 was taken in 1951 prior to any corrective work. The eroded areas are identified by hair-line gullies. The area in the Purdue Forage Farm; it lies in Sec. 1, T1S, R3W, Dubois County, Indiana. The arrow “A<sub>2</sub>” in Figure 16, which was taken in 1954, points to a farm pond constructed at point “A<sub>1</sub>” in Figure 15. Figure 16 shows several other ponds scattered over the farm. The dams were constructed in the drainageways to check erosion, to furnish water for cattle, and to raise the general water table.

By planimetering the areas of the watersheds above the ponds, on the airphotos, the yield of water contributed by each watershed can be determined and the amount of storage estimated. Some terracing has



Fig. 18. Hills of Sandstone-Shale—Lawrence County, Indiana. This area has good surface drainage through its many first order streams.

been accomplished and rye has been planted on the road embankments to prevent erosion. The terracing of the hillside fields directs runoff into designated channels. All this work retards runoff, reduces its amount, and delays time of concentration of peak discharge in the streams draining the area. The danger of excessive flooding is reduced.

#### *Floods*

Airphotos are excellent mediums for observing the extent to which bottom lands are flooded. Figure 17 shows the limits of inundation at the instant of photography of the particular area illustrated. By locating certain landmarks on the airphotos, high water marks can be established on the ground. Time erases high water marks and human beings forget where the marks have been. This information, which is so vital in the design of bridges and culverts both over the main stream and over its tributaries, is recorded on the airphotos and can be used when desired. Therefore, it is not necessary for the engineer to be "everywhere at once" in order to establish the high water line. The illustration furnishes other information, too. The channel may be traced in spite of the high water; it is outlined by trees. Areas of high ground on the valley floor can be bounded; chances are they are not really dry ground for some appear to be saturated; and therefore, untrafficable.

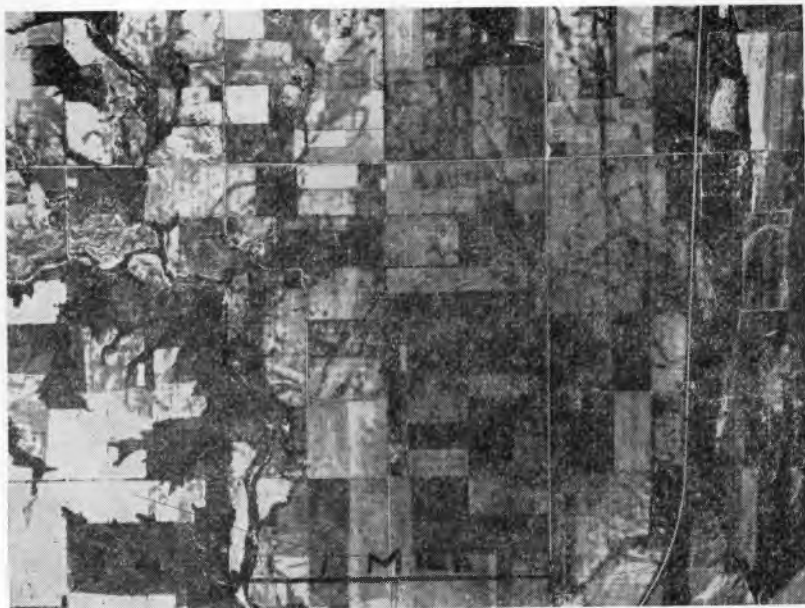


Fig. 19. Granular terrace—Vermillion County, Indiana, area well-drained internally. There is a lack of a developed surface drainage system. The dark gray tones of the infiltration basins give a mottled pattern to the otherwise uniform light gray tone of the granular material. Streams from the upland flow around this deposit of granular material.

The flood water flumes can be identified by their “current-swept” appearance; they mark the low spots in the flood plain, spots which are likely to contain organic soils.

#### *External and Internal Drainage*

*Excellent Surface Drainage.* An area is considered well drained externally if it has a fine-textured drainage net. This is an excellent quality from the standpoint of the rapid removal of excess precipitation, but the terrain presents engineering problems which are expensive and difficult to overcome. For instance, “cross-valley” highway construction of a highway would involve heavy cuts and fills.

Figure 18 illustrates an area of integrated drainage. The highway in the valley has a multiplicity of culverts and may be subjected to flooding by the main stream. The highway on the ridge has many sharp curves and some steep grades and may be damaged by landslides.

*Excellent Internal Drainage.* Granular terraces by virtue of their texture and topographic situation are usually well-drained internally. Because the rain water soaks into the soil, very few surface streams are





Fig. 20. Dead Furrows—Southern Indiana area poorly drained internally. Because of the impervious subsoil, tile drainage is impractical. The “dead furrows” are the parallel dark lines; they are dark because the soil is moist.

developed on such terraces. Their extent can be measured accurately by means of airphotos since their characteristic mottled pattern makes identification positive. (See Figure 19.) Highways can be built across granular terraces with very low embankments; they require shallow side ditches because drainage is internal. Infrequent equalizing culverts are all that might be required for draining the infiltration basins.

Granular terraces make excellent airport sites because of the high bearing strength of the materials and their good internal drainage.

*Poor Internal Drainage.* Soils areas which are poorly drained internally can be identified on airphotos. In Figure 20 the farmers have plowed their fields in such a manner that dead furrows are left between the “lands.” Since the surface soil drains fairly well the dead furrows carry the excess moisture from the top soil to ditches along the edges of the fields. This increases runoff and decreases time of concentration in the area. Whenever an engineer observes the “dead furrow” pattern on the airphotos of an area where highway construction is proposed, he “knows” the subsoils in that area are poorly drained and he wisely recommends a high-level profile for the roadway embankment.

*Poorly Drained Subsoils.* Poorly drained subgrades often cause pavements to disintegrate. Low altitude aerial strip photos can be used as photo maps to determine the extent of the damage to the pavement. (See Figure 21.) Frequently the “break-ups” occur in cut sections of

the highway where the subbase is in contact with the subsoil; the large patch (dark spot) is near the center of the "cut" (indicated by the shadow directly above the pavement).

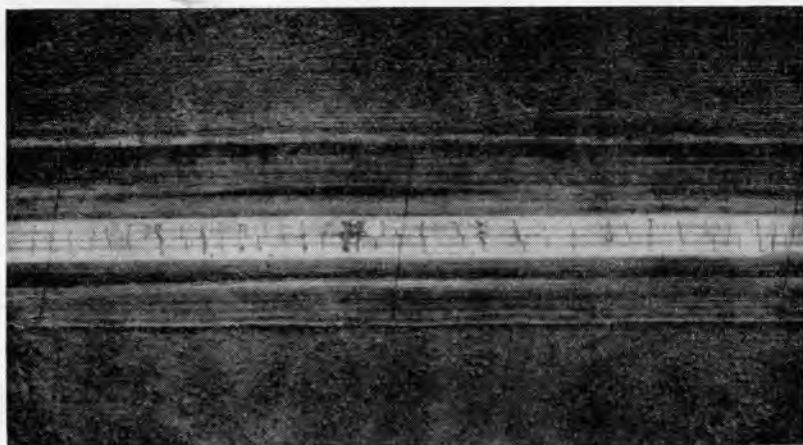


Fig. 21. U. S. 30—Northern Indiana. The disintegration of the pavement is due to poor drainage of the subgrade. (Chicago Aerial Industries, Inc., photo from Purdue files.)



Fig. 22. Landslides (L.S.) along county road in Switzerland County, Indiana. The road at the arrow in center appears much wider than at other points. This indicates that measures have been taken to correct the slide.



### *Landslides*

Landslides plague highways in the clay shale regions of the state. Most of the landslides are due to poor internal drainage of the soil. Excessive moisture causes the soil to become "fluid," and to "slide downhill." In Figure 22 the landslides appear to have been stabilized and the highway repaired. Landslides in Indiana, while they seem major, are mostly small in extent and it is difficult to identify them on the airphotos. In some cases the land has a horizontally "puckered" appearance.

The shale bedrock regions of the state can be identified on airphotos by their smooth, rounded landforms and dendritic drainage patterns. This informs the engineer where landslides are likely to occur. The two landslides in Figure 22 occurred at points where the stream is undercutting its left bank. Colluvial slopes (which are a combination of loose rock and soil) are other locations where landslides can occur; they are identified on the airphotos as fillets between the valley floors and the valley walls of the streams of the area.



Fig. 23. A stream "straightened" by a dredged ditch—Gibson County, Indiana. This picture, also, illustrates the effect of the clouds on aerial photography; the "white" cloud (C) blots out a portion of the terrain and its "black" shadow (S) can be mistaken for a muck area (i.e., an area of poor drainage).

### *Dredged Ditches*

The improvement of surface drainage is effected by dredged ditches. Considerable planning is required before a ditch is dredged. Airphotos can aid in the determination of the areas to be drained, the alignment of the ditch in its relationship to other existing drainageways, its extent, and even its outlet. Figure 23 shows a meander in the original drainageway cut off by the ditch. By shortening the stream, the gradient is increased which would be expected to increase the velocity and be conducive to rapid runoff. For example, airphotos can be used to record the condition of dredged ditches. The sides of a newly constructed ditch are "clean;" i. e., there is no vegetation to retard the flow. Dredged ditches can be identified by a dark gray line flanked by two "white" lines, usually. The water (or moist ditch bottoms) photographs in dark tones of gray while the spoil banks, being relatively unconsolidated and free-draining, are recorded in light gray tones. That the ditch in Figure 23 was needed is evidenced by the dark gray tones of the adjacent field, indicating poor drainage.

Occasionally records are lost or destroyed by fire; airphotos are an excellent means by which new maps are made. Another important item is that dredged ditches often connect with others in adjoining counties. The areas of watersheds and other drainage data can be determined without expense to the neighboring counties.

### *Subsurface drains*

Subsurface drains (farm tile) are used to remove excess precipitation from sandy and silty soils which have the inherent quality of good internal drainage but for some reason or other have restricted outlets to the areas in which they are found. Existing tile drains are "visible" on airphotos which have been taken shortly (say within 48 hours) after rains of sufficient intensity to saturate the soil. Figure 24 is an example. After the rain has stopped and the tiles start functioning the water is drawn from the soil adjacent to the drains. This makes that soil "dry" while the soil farther away from the drains is still wet. The dry soil is recorded on the airphotos in light tones of gray while the wet soil is recorded in dark tones of gray. The "fuzziness" of the lines is the result of the lack of uniformity of the soil texture, structure, consistency, etc., causing slightly unequal rates of flow of water through the soil. Airphotos of this type are important for they show whether or not the tiles are functioning. They also serve as photo maps of the subsurface drainage systems.

Pictures like Figure 25 are of value because they can be taken from a small plane after any hard rain. They serve as a record and can be used to show omissions or deficiencies in the tile system.

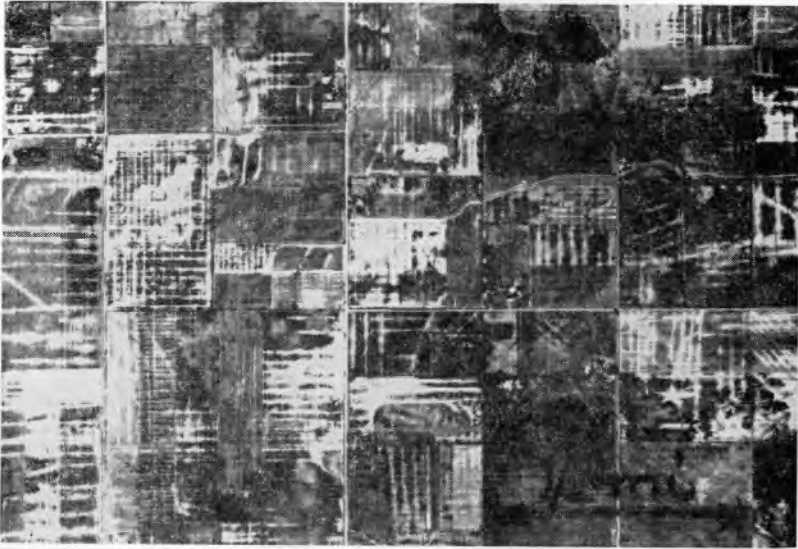


Fig. 24. "Visible" tile drains near the Indiana-Ohio state line east of Fort Wayne, Indiana. The "fuzzy" white lines give the locations of the field tiles. The crossed lines about 1 inch above the " $\frac{1}{2}$ " in the scale indicates 2 sets of tiles.



Fig. 25. Field tile—central Indiana. As in Figure 27 the "fuzzy" nearly white lines trace the network of subsurface drains.

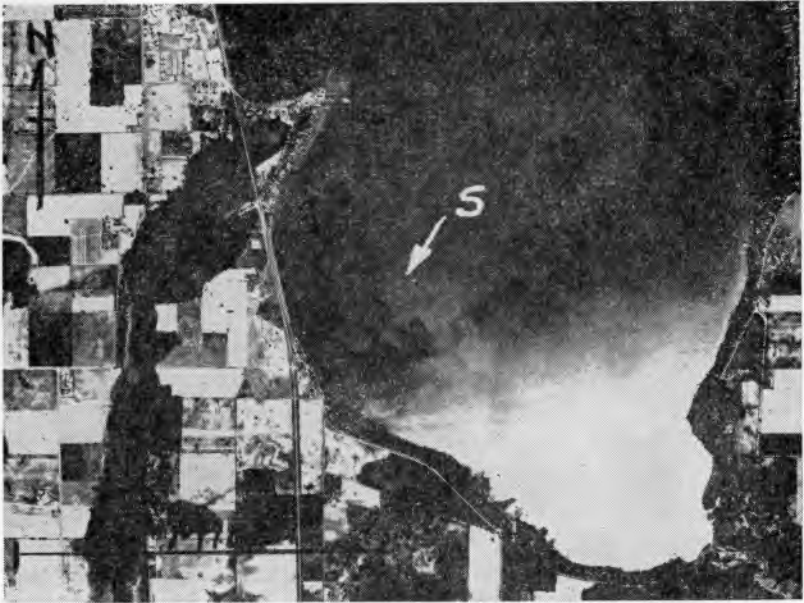


Fig. 26. "Visible" bottom of Lake Maxinkuckee. "S" indicates shallow water (light gray tone); in this case it is about 10 feet deep. The "white" spot is caused by the sun's rays being reflected into the camera.



Fig. 27. Settling Basins for water supply—Dubois County, Indiana. The varying tones of gray indicate degree of turbidity—light gray, turbid, and dark gray, clear.

### *Transparency*

If a lake or stream is "clear" and relatively shallow, its bed is often "visible" on airphotos. For instance, the areas having light gray tones within the lake in Figure 26 are regions of shallow water. Deeper water is indicated by the interspersed areas of dark gray tones. Such information can be of importance in the design of boat piers or in the location and design of bridges across inlets.

### *Turbidity*

Tonality may be used within limits to estimate the degree of mineral turbidity of a stream, lake, or reservoir. As the number of particles held in suspension increases, the amount of surface area from which light is reflected increases and the tones of gray of the image of the body of water on the airphoto becomes progressively lighter. The light gray tones of the inlet sections of the reservoir in Figure 27 indicate muddy water received from the watersheds. An engineering problem is developing; the muddy sections are filling with sediment which in turn is reducing the amount of water stored. Someday they will have to be



Fig. 28. The heart of Indianapolis.

cleaned out, by-passed, enlarged, or abandoned. By studying the airphotos of the vicinity the problem might be solved—perhaps an adjacent watershed would furnish a greater yield even if it would require the construction of a new dam.

### *Sewer Design*

Large scale airphotos have become almost a necessity in the design of a city sewer system. Types of surfaces can be identified and the pervious areas such as gardens, lawns, and parks, and impervious areas such as roofs, sidewalks, and streets are measured. The data can be used in runoff formulas in determining the required capacities of the sewers. Although Figure 28 is a small scale airphoto, it illustrates the magnitude of the problem. Quite often airphotos can be used to advantage in selecting the routes of trunk sewers—the buildings that will be affected or the sections of the city that will be served.

### *Old Channels*

Preglacial and interglacial drainageways filled with granular materials are called “old” channels. They are identified on the airphotos as linear depressions having dark gray tones. Ordinarily they are streamless “valleys” because drainage is internal. However, occasionally



Fig. 29. Old Channel in Madison County, Indiana. “GP” indicates a water-filled gravel pit.

one may have an insignificant (misfit) stream meandering through its entire length. A ditch has been dredged in the old channel in Figure 29 in an effort to lower the water table. The height of the water table can be observed by the elevation of the water in the gravel pit. Old channels are natural reservoirs for water supply. They, also, are sources of granular materials.

#### *Road Alignment*

When does a mile measure a mile and a quarter? Answer: When a road on a section line by-passes a sinkhole or a depression containing unstable soil. Figure 30 is an example of the latter. Perhaps the road would have been placed on the quarter-section line to the south had airphotos been available at time of construction. Too much stress cannot be placed upon the importance of airphotos in the planning of highway construction.

#### *Vegetation in Channels*

Trees, bushes, and hydrophylic plants like to grow in drainageways, especially in intermittent streams. Figure 31 shows this condition by the velvety textural appearance of the channel and its indefinite width. "Clean-out" plans can be made with airphotos. The lengths of sections



Fig. 30. County road by-passing muck pocket—Pulaski County, Indiana.



requiring attention can be measured. The type of vegetation, whether the growth is dense and prolific, or sparse, can be determined in this "armchair method" of engineering. Certainly much time can be saved in making the survey from airphotos.



Fig. 31. Vegetation in stream channel, Warren County, Indiana.



*Strip Mines*

While Nature is the chief disrupting agent of drainage systems, man has contributed his share to deranging the hydrologic features of the terrain. Strip mining operations such as those shown in Figure 32 often change the surface of the ground completely. The ground is loosened and made pervious. Ridges and valleys are created. Vegetation is removed. Ditches have to be dredged to carry the waters of the streams around the pits. This is a problem for the engineer because water deflected from one watershed to another may tax the carrying capacity of an existing highway structure to the point of failure. If that should



Fig. 32. Strip mines in southwestern Indiana. The mining operations have completely disrupted surface drainage.

happen, airphotos could be of use in determining the increase in watershed area for data to be used in the design of a new structure. On the other hand, if the airphotos were studied in time, the excess water might be directed into a section of the "worked-out" mine and danger of bridge failure averted. The pits become filled with water and lakes are formed. If a highway is built across a stripped area, equalizing culverts have to be built where the embankment is constructed across water-filled pits. Airphotos make possible the easy revision of existing drainage maps of a strip mine area.

### *Seasonal Variations*

The photograph of a low water condition in a reservoir sometimes reveals the amount of water used in relation to the supply. The amount used can be measured photogrammetrically. In Figure 33 the "white" band surrounding the "lake" (the black area) is the result of the drying of the recently emerged portion of the reservoir bottom; the outer boundary marks high water level and its inner boundary is the "present" or low water level. The sediments delivered to the reservoir by the feeder streams are extremely silty; and dry silt is recorded on the photos in very light tones of gray (often white). The photograph illustrates a very definite problem—that of sedimentation in the reservoir. Successive periodic airphotos can be used to determine its rate.

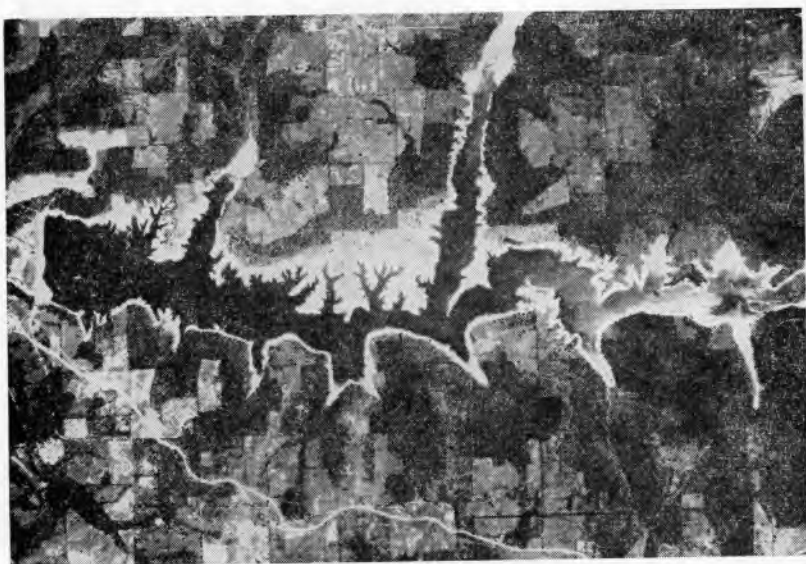


Fig. 33. Fluctuation in water level—reservoir in Martin County, Indiana.

*Progress Pictures*

Airphotos can be used for progress records of drainage structures. In Figure 34, pier construction is under way for the second bridge of a dual highway. The river appears to be at above normal stage; it has flooded the borrow pit.



Fig. 34. Bridge construction—U.S. 31 at Edinburg, Indiana.

### Field Maps

A drainage strip map prepared from airphotos can be used for field checking existing highway structures. It is especially useful if records of construction have been lost or inadvertently destroyed. The map in Figure 35 was prepared by marking the drainageways on the airphotos and tracing them directly. Thus a fairly accurate large-scale map was obtained, one having sufficient space for the recording of the field notes.

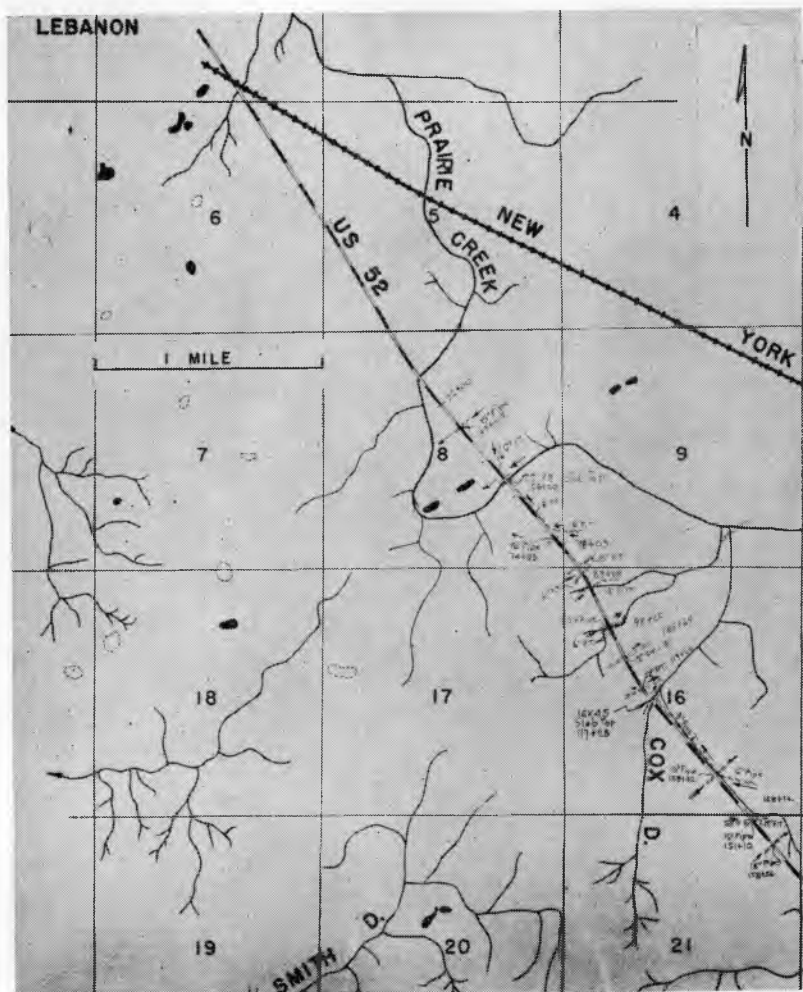


Fig. 35. Drainage Map for a section of U. S. 52 southeast of Lebanon, Indiana. This map has been used to field check bridges, culverts, and tile drains.

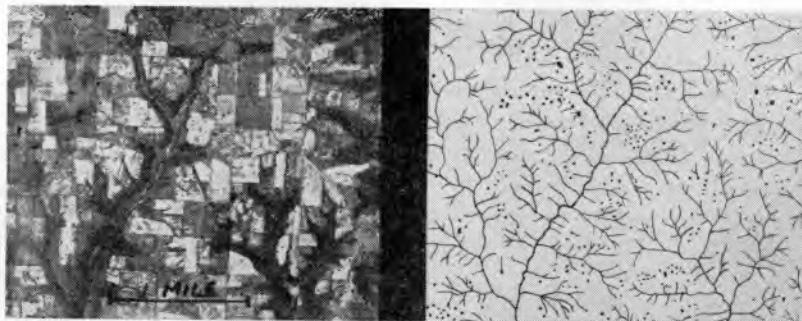


Fig. 36. Karst region—Monroe County, Indiana. Dots represent sinkholes.

## USE OF AIRPHOTO DRAINAGE INFORMATION IN THE ENGINEERING SOILS MAPPING PROGRAM

Airphoto identification of soils involves the analysis of several pattern elements among which are landform, tonality, land use, and drainage pattern (7). As pointed out in Figures 18 and 19, an area either does or does not have good surface drainage. This condition is a clue to the perviousness or imperviousness of the soil. It follows then that certain types of soil have excellent internal drainage while other types are extremely plastic and resistant to the flow of ground water. The soils which have good surface drainage are usually poorly drained internally and vice versa. Knowing these characteristics, the airphoto interpreter can use the drainage pattern element effectively in his identification of soils for engineering purposes.\*

### *Role of Drainage Patterns in Soils Identification*

Although sinkholes do not indicate positively that the bedrock of an area is limestone, their presence in Figure 36 is the result of solution in the limestone. Having identified the bedrock, it is a logical deduction, considering the medium-textured subdendritic drainage pattern, to state that the soils are clays which have fairly good internal drainage.

### *Status of Engineering Soils Mapping*

Paralleling the drainage mapping program in the Joint Highway Research Project is the Engineering Soils Mapping Program. Figure 37 shows the status of this program. The maps are compiled from aerial photographs with a minimum amount of field checking.

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\* Drainage patterns were discussed in a paper entitled "Regional Drainage Patterns of Indiana," which was presented at the 33rd Annual Purdue Road School, in February, 1947.

# USERS OF DRAINAGE INFORMATION OBTAINED FROM AIRPHOTOS

That drainage information obtained from airphotos has been of use to engineers is evidenced by Table III. This table lists many of the agencies which have requested drainage maps or relative information during the past several years.

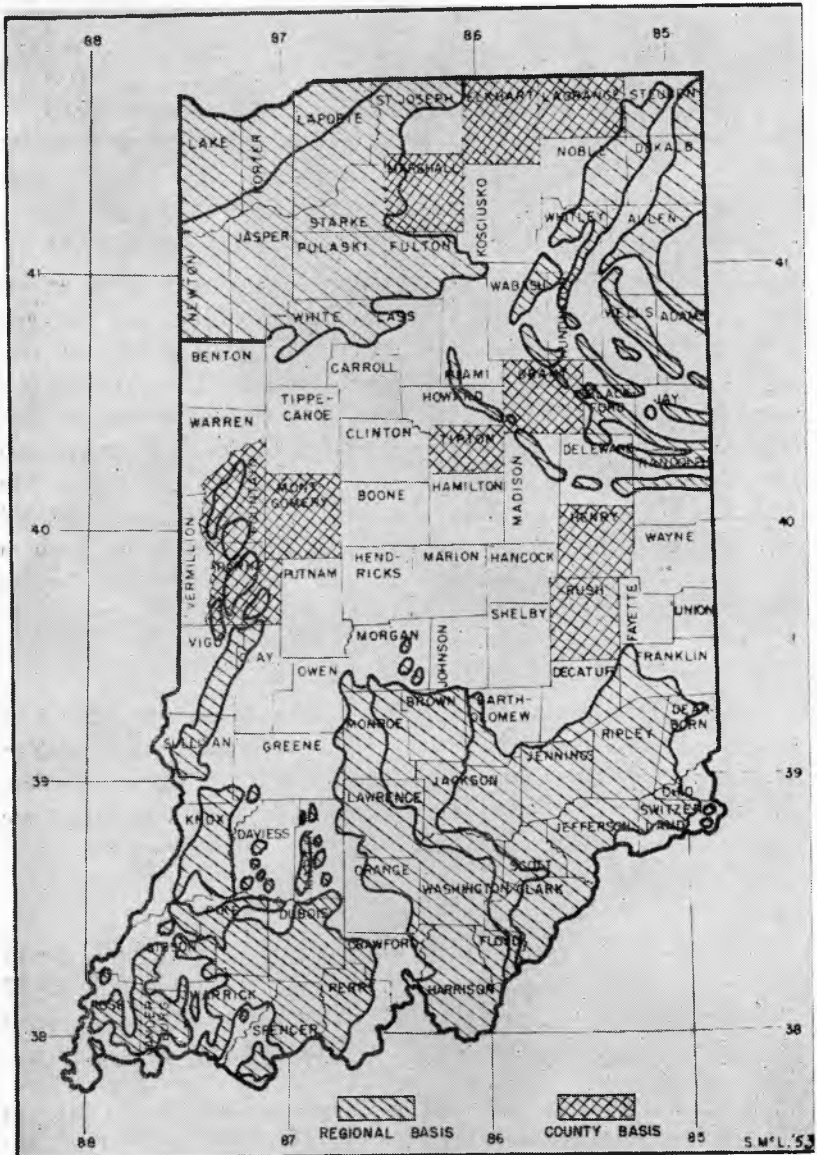


Fig. 37. Status of Engineering Soils Mapping, March, 1955.

TABLE III

AGENCIES WHICH HAVE REQUESTED DRAINAGE MAPS  
OR RELATIVE INFORMATION

Aluminum Co. of America	Lafayette, Indiana
Armco Drainage & Metal Products, Inc.	Middletown, Ohio
Associated Architects & Engineers	Peru, Indiana
W. C. Babcock Construction Co.	Rensselaer, Indiana
W. J. Barrett, Hancock Co. Rd. Supvr.	Greenfield, Indiana
Better Roads Magazine	Chicago, Illinois
Bureau of Government Research, Indiana University	Bloomington, Indiana
Bureau of Public Roads	Washington, D. C.
T. M. Bushnell, Ag. Exp. Sta., Purdue University	Lafayette, Indiana
Committee on Christian Education	Winona Lake, Indiana
Conservation Department	Indianapolis, Indiana
Cornell University, College of Engr.	Ithaca, New York
Corps of Engineers	Louisville, Kentucky
County Agents	Various Counties
Division of Water Resources	Indianapolis, Indiana
Farmcraft Service, Inc.	Oxford, Indiana
County Surveyors	Various Counties
Wm. Gehring, Inc.	Rensselaer, Indiana
Geology Dept., Indiana University	Bloomington, Indiana
Girdler Corp.	Terre Haute, Indiana
J. E. Greiner Co.	Baltimore, Maryland
Ground Water Branch, U.S.G.S.	Indianapolis, Indiana
Harker Engineering & Office Supply Co.	Martinsville, Indiana
The Highway Magazine	Middletown, Ohio
Highway Research Board	Washington, D. C.
Holabird & Root & Burgee, Consultants	Chicago, Illinois
R. M. Huff, Earlham College	Richmond, Indiana
State Highway Department of Indiana	Indianapolis, Indiana
Indiana Flood Control and Water Resources Committee	Indianapolis, Indiana
Indiana Lake and Stream Survey, Indiana University	Bloomington, Indiana
Indianapolis Star Magazine	Indianapolis, Indiana
Jasper County Abstract Co.	Rensselaer, Indiana
Journal of the Cuban Soc. of Engrs.	Havana, Cuba
Lake County Plan Comm.	Crown Point, Indiana
Lake County Title Co.	Crown Point, Indiana
Layne-Northern Co., Inc., Well Drillers	Mishawaka, Indiana
Mississippi Geological Survey	University, Mississippi
New York Central Railroad	Indianapolis, Indiana
Ohio Department of Highways	Columbus, Ohio
Seymour Ouzer	Rolla, Missouri
Pierce & Gruber, Consultants	Indianapolis, Indiana
Planning Survey, Miss. Highway Dept.	Jackson, Mississippi



Prairie Farm Rehabilitation Office  
 Purdue University Library  
 Ranney Method Water Supplies, Inc.  
 Richmond Water Works Corp.  
 Rock Island Refining Co.  
 St. Joseph's College  
 Soil Conservation Service, U.S.D.A.  
 Soil Conservation Service, U.S.D.A.  
 Soil Testing Services, Inc.  
 T. H. Thornburn, University of Illinois  
 State Highway Commission of Maine  
 U. S. Geological Survey  
 University of Notre Dame, Dept. of C.E.  
 Clyde E. Williams & Associates  
 J. H. Zumberge, Geol. Prof., University  
 Michigan

Regina, Saskatchewan, Canada  
 Lafayette, Indiana  
 Columbus, Ohio  
 Richmond Indiana  
 Indianapolis, Indiana  
 Collegeville, Indiana  
 Logansport, Indiana  
 Rensselaer, Indiana  
 Chicago, Illinois  
 Urbana, Illinois  
 Augusta, Maine  
 Indianapolis, Indiana  
 South Bend, Indiana  
 South Bend, Indiana  
 Ann Arbor, Michigan

## CONCLUSIONS

The following conclusions have been drawn concerning the value of airphotos in connection with their hydrologic application by engineers:

1. Airphotos exhibit a wealth of drainage information.
2. Airphoto drainage information can be transferred to maps for engineers' use.
3. Use of airphoto drainage information can save time and money for engineers and their clients.

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